भारतीय मानक
Indian Standard

IS 16864 : 2018

पॉलीकार्बोनेट सुरक्षा कवच — विशिष्टि

Polycarbonate Protective Shield — Specification

ICS 83.140.99

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December 2018 **Price Group 8**

Plastics Sectional Committee, PCD 12

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Plastics Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

Polycarbonate protective shields are protective equipment which are generally carried by public safety officials whilst engaged in operational duties, and during training. These are also used by civilians engaged in activities where the risks of attack and assault are similar, for example, private security personnel, bullion handlers, escorts and couriers.

The purpose of this standard is to provide confidence to the user that the polycarbonate protective shields when used, will protect from the attack and assault in the course of their duties.

The polycarbonate shields are generally used in conjunction with other items of protective clothing and equipment such as helmets, body and limb protectors, gloves and protective footwear.

These shields are typically used for riot control in public areas and correctional facilities. Other uses of these shields are for securing the scene, for example, clearing a building, crowd control and for protection or herding in an incident involving animals etc.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

POLYCARBONATE PROTECTIVE SHIELD — SPECIFICATION

1 SCOPE

1.1 This standard specifies the requirements, methods of sampling and tests for polycarbonate protective shield.

1.2 Polycarbonate protective shield is intended for use by the public safety organizations or others who might be exposed to attack and assault in the course of their duties, for use as personal protection equipment in operational situations and in training etc.

1.3 This standard is not applicable for bullet and explosion proof protective shields.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated:

IS No./Other publication	*Title*
4905 : 1968	Methods for random sampling
13360	Plastics — Methods of testing
(Part 3/Sec 1) : 1995	Physical and dimensional properties, Section 1 Determination of density and relative density of non-cellular plastics
(Part 4/Sec 1) : 2000	Rheological properties, Section 1 Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics (*first revision*)
(Part 5/Sec 4) : 2013	Mechanical properties, Section 4 Determination of izod impact strength (*first revision*)
(Part 5/Sec 7) : 1996	Mechanical properties, Section 7 Determination of flexural properties
(Part 6/Sec 17) : 2013	Thermal properties, Section 17 Determination of temperature of defection under Load — Plastics and ebonite (*first revision*)
(Part 8/Sec 9) : 1997	Permanence/chemical properties, Section 9 Determination of resistance to environmental stress cracking (ESC) — Bent strip method
(Part 9/Sec 5) : 2010	Optical properties, Section 5 Determination of haze and luminous transmittance of transparent plastic
14443 : 1997	Polycarbonate sheets — Specification
ISO 4892-2 : 2013	Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps
ISO 11357-2 : 2013	Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and glass transition step height
ASTM D1044-13	Standard test method for resistance of transparent plastics to surface abrasion

3 REQUIREMENTS

3.1 Material Requirements

3.1.1 The polycarbonate material for manufacture of body of the protective shield shall be natural.

NOTE — The polycarbonate material may contain additives, processing aids and stabilizers (for example UV stabilizers), etc.

3.1.2 The polycarbonate material shall also comply with the requirements given in Table 1 when tested as prescribed in col 4 of the Table 1.

Table 1 Requirement for Polycarbonate Material

(*Clause* 3.1.2)

Sl No.	Characteristic	Requirement	Method of Test, Ref to IS
(1)	(2)	(3)	(4)
i)	Melt Flow Index, g/10 min (at 300ºC under 1.2 kg load when measured after pre-drying of the material at 120 ± 5ºC upto 4 h)	1.5 to 8 (for extrusion/thermoforming) 8 to 15 (for injection moulding)	IS 13360 (Part 4/Sec 1)
ii)	Specific gravity	1.19 to 1.22	IS 13360 (Part 3/Sec 1)
iii)	Flexural modulus, *Min*, MPa (with crosshead speed of 1.2 mm/min and a span to depth ratio of 16 to 1 (test specimen size, 4 mm × 10 mm)	2 200	IS 13360 (Part 5/Sec 7)
iv)	Izod impact strength, notched, *Min*, kJ/m^2 (test specimen thickness of 3 mm and notch radius of 0.25 mm)	60	IS 13360 (Part 5/Sec 4)
v)	Deflection temperature under load at 1.82 MPa, *Min*, °C	120	IS 13360 (Part 6/Sec 17)

Table 2 Requirements for Polycarbonate Body of the Shield

(*Clause* 3.2.5)

Sl No.	Characteristic	Requirement	Method of Test, Ref to IS/Annex
(1)	(2)	(3)	(4)
i)	Dart drop impact, *Min,* J (at 27ºC)	150	Annex B
ii)	Light transmission, percent, *Min*	83	IS 13360 (Part 9/Sec 5)
iii)	Flammability (test specimen thickness 3.18 ± 0.13 mm)	94 HB class	Annex C

3.2 Physical Requirements

3.2.1 *Description*

3.2.1.1 The polycarbonate protective shield shall be of suitable design, shape and curvature as agreed to between the purchaser and the supplier. Ribs shall be provided all along the edges of the polycarbonate body of the shield.

NOTES

1 The shape of the shield should be such that it gives maximum coverage to the user.

2 The design of the shield should be such that during handling, the vision area should not foul with the resting surface.

3.2.1.2 The total weight of the polycarbonate protective shield shall be 3.4 kg (*max*). The weight of polycarbonate body of the shield shall be 2.6 kg (*min*).

NOTE — Total weight, weight distribution and design of the shield must not negatively impact the user's ability to perform tasks required during tactical operations.

3.2.2 *Dimensional Requirements of Polycarbonate Body of the Shield*

Length : 955 mm + 45 mm
– 25 mm

Breadth : 580 mm ± 20 mm

Breadth concave : 620 mm ± 10 mm or any other proven better shape

Thickness (*Min*) : 3.0 mm

3.2.3 *Manufacturing Process*

The polycarbonate protective shield shall be manufactured by thermoforming or injection moulding process adhering to code of good fabricating practices as given at Annex A.

3.2.4 The polycarbonate body of the shield shall have abrasion resistance surface coating on both the surfaces.

NOTE — The composition of the coating and the application techniques are not specified in this standard.

3.2.5 The polycarbonate body of the shield shall also comply with the requirements given in Table 2 when tested as prescribed in col 4 of the Table 2.

3.2.6 *Polycarbonate Material Identification*

The polycarbonate body of the shield shall meet all the test requirements detailed below. The test specimen for the following tests shall be taken from flattened area of the polycarbonate body of the shield.

3.2.6.1 *Fourier transform infrared (FTIR) spectroscopy*

The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the specimen versus the reciprocal wavelength (cm^{-1}) or wavenumber of the radiation. The infrared spectra obtained by this method shall consist of a minimum wavenumber range of 4000 — 400 reciprocal centimetres. Signature peaks for polycarbonate are 1770 cm^{-1} assigned to C=O and a set of three peaks in the range of 1000-1300 cm^{-1} assigned to C-O. Library matching shell confirm to at least 95 percent.

3.2.6.2 *Differential scanning calorimetry (DSC)*

The mid-point of glass transition temperature of the test specimen measured in the second heating cycle shall be above 140 °C when tested in accordance with the test method prescribed in ISO 11357-2.

3.3 Performance Requirements

3.3.1 *Resistance to Vandalism*

The polycarbonate body of the shield shall have impact resistance of level 'A3' when tested for vandal resistance as per the test method prescribed in Annex C of IS 14443.

3.3.2 *Resistance to Forced Entry*

The polycarbonate body of the shield shall have resistance of level 'B3' against penetration when tested for resistance to forced entry as per the test method prescribed in Annex D of IS 14443.

3.3.3 *Resistance to Surface Abrasion*

The test specimen of polycarbonate body of the shield when tested for resistance to surface abrasion in accordance with ASTM D1044 for 100 cycles under 500 g load, shall have haze percent not more than 20 percent.

3.3.4 *Handle Requirements*

3.3.4.1 Grips and supports must allow the user to comfortably hold and position the polycarbonate protective shield.

3.3.4.2 *General requirements of handle and other accessories of polycarbonate protective shields*

a) Manufacturing process for handle should be gas-assisted injection moulding (GAIM);

b) Material for handle should be polymeric, preferably polycarbonate;

c) Integration of handle to polycarbonate sheet should be done using structural adhesive;

d) Elastomeric bushes and washer system should be used for nut and bolt system;

e) Metallic bolts, if used, shall be SS304 hex-headed M6 bolts; and

f) Nut and bolts system should preferably be self-locking.

NOTES

1 The assembly of the various components (handle, flat polycarbonate sheet, arm rest, etc.) with polycarbonate shield body should be such that polycarbonate shield is not stressed and there is handle cushioning provided through elastomeric bushes and washer system.

2 In cases, where protective shield constructed with the inner flat polycarbonate sheet from inner side and handle is assembled through nut and bolts through a hole, the shield body should have a horizontal groove after the deformation for the displacement under the loading condition. This will help in avoiding stress on polycarbonate shield at the assembled point.

3 Following adhesives are recommended for integrating the handle on polycarbonate sheet:

a) Cyanoacrylate based adhesives like permabond UV glue.

b) Weld-on plastic adhesives.

3.3.5 A list of accessories conventionally used in polycarbonate protective shield is given in Informative Annex D.

Fig. 1 and 2 illustrate typical examples of polycarbonate protective shields, their components and design features. Fig. 1 and 2 are illustrative and for information only.

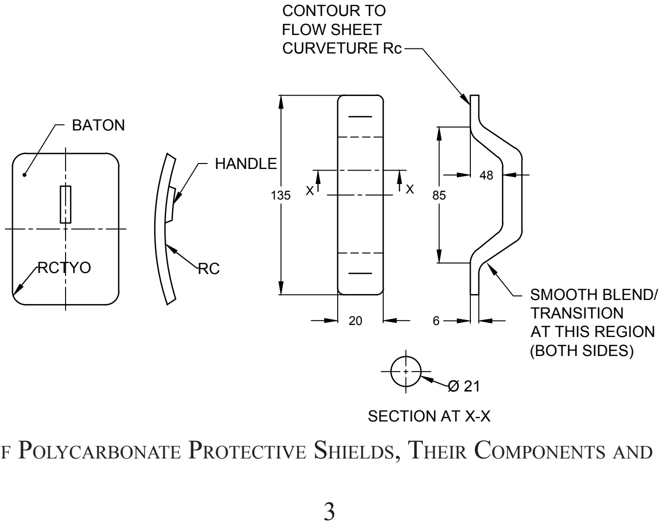
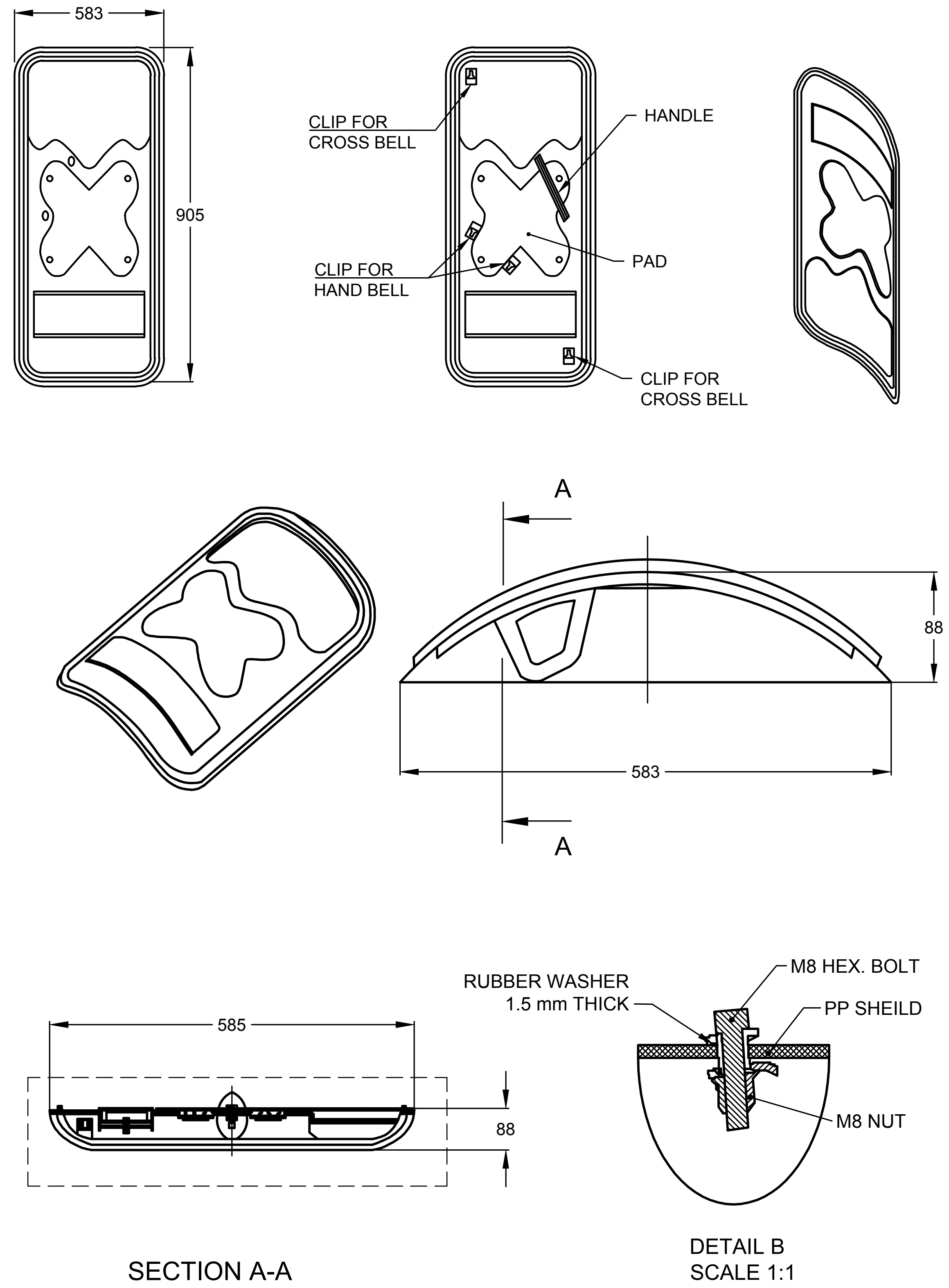


FIG. 1 EXAMPLE OF POLYCARBONATE PROTECTIVE SHIELDS, THEIR COMPONENTS AND DESIGN FEATURES



All dimensions in millimetres.

FIG. 2 EXAMPLE OF POLYCARBONATE PROTECTIVE SHIELDS, THEIR COMPONENTS AND DESIGN FEATURES

3.4 Maintainability Requirements

3.4.1 *Resistance to Environmental Stress Cracking*

Environment Stress Cracking Resistance (ESCR) test shall be performed on polycarbonate body of the shield (with protective coating) by constant strain method as per IS 13360 (Part 8/Sec 9).

The test specimen shall be taken from the polycarbonate body (coated) of the shield as flat strip of size 125 mm × 15 mm cut from centre. The test specimen shall be conditioned at 27 ± 2°C for at least 24 h to relieve internal stresses.

Test shall be carried out on a set of three test specimens under a constant strain of 0.5 percent at 27 ± 2°C. Chemicals, namely, 10 percent hydrochloric acid solution, 10 percent sulphuric acid solution, kerosene, petrol, diesel and Molotov cocktail, shall be applied on the test specimen. The exposed surface of the test specimen shall be examined after 10 min for signs of cracks, crazes, surface changes or pealing of coating, if any.

NOTES

1 Chemical should be applied or wiped gently on/from the surface using cotton. Care should be taken not to touch cut edge of the test specimen; this can adversely affect test results.

2 Another set of test specimen exposed to the same environmental conditions without the chemical acts as control. These test specimens should be used as reference for comparing with exposed strips.

3.4.2 *Weathering Resistance*

The test specimen when tested for weathering resistance in accordance with ISO 4892-2, shall be evaluated for retention of light transmission before and after exposure time of 3 000 h (*Min*). The light transmission of the test specimen after exposure for 3000 h shall not be less than 70 percent.

NOTE — Measurements should be carried on pre and post exposure test specimen at an interval of 1 000 h or as agreed to between the purchaser and the supplier.

4 PACKING AND MARKING

4.1 The polycarbonate protective shield shall be suitably packed as agreed to between the purchaser and the supplier.

4.2 Each polycarbonate protective shield shall be permanently marked with the following:

a) Indication of the source of manufacture and trade-mark, or the company responsible for placing the product in the market, if any;

b) Batch No.;

c) Month and year of manufacture;

d) Best use before…….. (month and year to be declared by the manufacturer); and

e) Any other information required by the statuary authority.

In addition to the above, the following information shall also be given in English/Hindi/regional language and may be included in a separate leaflet placed on the product:

a) Types of threats that the shield is designed to protect against;

b) Instructions for proper use as intended by the supplier;

c) List of components and required accessories provided with the shield;

d) Instructions for assembly and precautions regarding installation of attachments or modifications to the shield (if required);

e) Care and maintenance instructions;

f) Recommended storage conditions and life expectancy under those conditions; and

g) Availability of replacement parts (optional).

4.3 BIS Certification Marking

The polycarbonate protective shield may also be marked with the Standard Mark.

4.3.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations made thereunder. The details of the conditions under which the licence for use of the Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

5 SAMPLING

The samples of the polycarbonate protective shields shall be drawn and the criteria for conformity determined as prescribed in Annex E.

ANNEX A

(*Clause* 3.2.3)

CODE OF GOOD FABRICATING PRACTICES

A-1 Polycarbonate can be processed into useful end products by any of the usual processing techniques like extrusion, blow moulding, injection moulding etc. Selection of processing equipment, processing conditions and tool designing plays extremely important part in achieving best possible performance in end products made out of polycarbonate.

Polycarbonate sheets are amenable to practically all sorts of forming and fabricating techniques in comparison to other thermoplastic sheets. Adoption of improper practices, however, can lead to unacceptable performance level at the end use. This code of good fabricating practices highlights the areas of critical importance in forming and fabrication of polycarbonate sheets. It cannot, however, be treated as a complete guide to fabricating or forming. Experts in this field should invariably be consulted on various aspects especially when the end use is of critical importance.

A-2 FORMING

For production of limited number of large simple parts with uniform wall thickness, forming of plastic sheets has been found most economical route of production. Polycarbonate sheets are readily adoptable to standard forming techniques. Polycarbonate sheets, however, cool very rapidly and to achieve good results the forming machines should invariably be equipped with its own heating devices. To avoid blistering and consequent brittleness in the end product, polycarbonate sheets must be pre-dried especially if the forming operation is carried out at temperature over 160°C. The clamping frame should preferably be heated to prevent heat loss of heated sheets through the frame. Since polycarbonate sheets cool very fast, the forming should be done rapidly as soon as the sheets reach desired temperature. Demoulding should also be carried out quickly as soon as the material is rigid but still hot to touch.

A-2.1 Moulds

Wood, filled or unfilled polyesters, epoxies and metal can be used as mould material. To avoid thermal shock to polycarbonate sheet, materials which are not good conductor of heat are preferred tooling materials. If use of metal is must, the mould should be heated to 120-125°C. Generous radii of at least equal to wall thickness of the product should be provided in the tool. Draft angles of 5-7° for male moulds and 2-3° for female moulds are recommended. A shrinkage factor of 0.5 to 1 percent should be considered while designing the tool. To avoid air entrapment and consequent marks on the product surface, too smooth a mould surface should be avoided. Minute air channel can be provided on the mould surface by use of medium sand paper or fine steel wool. Adequate number of vacuum holes of 0.5 to 0.75 mm diameter should be provided in the mould to facilitate removal of air from between mould surface and polycarbonate sheet. To speed up air evacuation, back drilling of the holes with larger diameter drill can be adopted. Normally, release of product from a properly designed mould should not pose a problem. If difficulty is encountered, release agents like silicone spray, polytetrafluoroethylene spray, zinc stearate, talcum powder, etc, can be used. However, when the part has to undergo finishing operations like painting, printing or bonding, silicone or teflon spray should not be used.

A-2.2 Pre-drying

Polycarbonate sheets are to be pre-dried before forming in hot air circulating oven maintained at 125 ± 3°C. The air volume in the oven should be exchanged six times in an hour to remove water vapour. Polycarbonate sheets, after removal of masking, should be hung vertically or be placed in horizontal racks with a separation of about 25 mm. After pre-drying the sheets should be used within few hour depending on sheet thickness and local atmospheric condition. Drying time varies with sheet thickness as given in Table 3.

Table 3 Drying Time

(*Clause* A-2.2)

Sl No.	Sheet Thickness mm	Drying Time h
(1)	(2)	(3)
i)	0.75	0.50
ii)	1.00	1.00
iii)	1.50	1.50
iv)	2.00	3.00
v)	3.00	4.00
vi)	4.00	10.00
vii)	5.00	16.00
viii)	6.00	24.00
ix)	8.00	36.00
x)	9.50	40.00
xi)	12.00	48.00

A-2.3 Heating

Production of good parts depends on controlled and uniform heating of polycarbonate sheets. Sandwich type heaters are recommended. Normal forming temperature is between 185-210°C range. Best result is achieved at around 200°C. Heating rate is usually affected by power fluctuation and air draught and should be controlled. To avoid hot spots and to achieve forming temperature at the edges, slower heating is recommended. Clamping frame should be pre-heated to 120-130°C.

A-2.4 Cooling

Due to high heat distortion temperature of polycarbonate, products formed from polycarbonate sheets retain sufficient rigidity even at 125°C and can be demoulded at this temperature. This enables to achieve lower cycle time in the forming process.

A-2.5 Techniques

All thermo-forming techniques like plug assisted and unassisted vacuum forming, free blowing, pressure forming or snap back forming can be used to give desired shapes to polycarbonate sheets. Polycarbonate sheets can also be cold formed at relatively lower temperature of about 160°C by techniques like drape forming, matched mould forming, hot line bending, etc. In such cases pre- drying of sheets can be avoided. Polycarbonate sheets are heated in an oven on felt covered supports. Tools are to be pre-heated to 80°C. Since embossing of polycarbonate thin sheets is widely employed in fabrication of membrane switches this technique is discussed in slightly more detail in the next section.

A-2.5.1 *Embossing*

Embossing is used to form raised areas in thin polycarbonate sheets. Thickness of up to 0.25 mm is readily amenable to embossing while thickness up to 0.50 mm can be embossed only in certain configuration. Due to high stress build up during embossing operation, life of membrane switch could be affected significantly and life testing is always recommended. Embossing dies can be made from metals like zinc, magnesium, aluminium and steel and-non-metals like polyesters, silicone rubbers, etc. The clearance between male and female portions of the die should be approximately equal to sheet thickness. Draft angle of minimum 3° on both male and female tools is recommended. To reduce fatigue and impact failure possibilities all corners should have radii of equal or greater than the sheet thickness. The embossing width should be equal or greater than 5 times the sheet thickness. The embossing height should not exceed 2.5 times the sheet thickness (excluding adhesive and liner) with sheet thickness included in the measurement. Spacing between embossed areas should be 1.5 mm minimum to limit distortion after embossing.

A-2.6 Annealing

Stress relaxation through annealing in formed products should preferably be avoided. Frozen in stress can be reduced by adopting better processing parameters and good machines. In certain cold formed products, the stress can be relieved by heating at 130-135°C for 1 h per 25 mm of sheet thickness. The impact strength of the products, however, might be reduced after this operation. Since the products tend to deform while releasing stress, they should be kept in forms during the process.

A-3 INJECTION MOULDING

To injection mould polycarbonate, plunger type machines are positively to be avoided. Screw pre-plasticising type injection moulding machines preferably with medium to high injection pressure capability usually give satisfactory result. Machines equipped with precise temperature pressure and speed control give optimum productivity and quality parts.

Hourly plasticising capacity of the machine should be adequate to take care of total part weight produced during the hour. Too high a capacity may lead to poor strength in the part due to thermal degradation resulted from high residual time of the melt in the barrel. Lower capacity will extend the cycle time, thereby reducing the productivity. Shot capacity of the injection moulding machine should be at least 20 to 30 percent more than the part weight including sprue and runners to avoid incomplete parts. Part weight should also not be lower than 20 percent of the shot capacity to avoid thermal degradation of the melt remaining in the heated machine barrel for longer period of time. The clamping force of the machine is usually decided on the basis of projected area of the part and injection pressure which in turn depends on part intricacies, flow length and thickness of the part. To take an example, a part with 400 cm^2 projected area being moulded at an injection pressure of 1 000 kg/cm^2 will need a machine with minimum clamping force of 200 tonne (it is assumed that only 50 percent of injection pressure is actually transmitted into the mould cavity due to pressure drop in flow path).

L/D ratio of the plasticising screw of an injection moulding machine processing polycarbonate should be 20:1 and the compression ratio should be in the range of 1:2 to 1:2.5. Shut-off-valves cause material hang over and consequent thermal degradation resulting in poor quality parts. Short free flow nozzles with a minimum opening of 3mm are recommended for processing of polycarbonate. Good nozzle temperature control improves part quality and eliminates melt drooling.

Since polycarbonate is used in components of precision engineering applications, dimensional accuracy and high-performance levels have to be assured during production of the parts. Parameters like temperature, pressure and speed, influence part quality immensely and they are to be precisely controlled to ensure quality parts. The machine should be able to control the temperature within ± 2°C of the settings. Modern injection moulding machines are equipped with microprocessor control and various control options like variable pressure and speed.

A-3.1 Injection Moulds

Sprue bushing in an injection mould should have a generous taper, should be well polished and hardened. The sprue diameter should be larger than the nozzle orifice by 1 mm. The sprue bushing radius should be 1 mm larger than that of the nozzle. The small end of the sprue should be at least 4 mm in diameter. In case of direct sprue gating, cooling opposite the sprue avoids sink marks and cooling in the sprue area reduces cycle time. Short full round primary runners with at least 5 mm diameter are preferred. For long flow path hot runners are recommended. Cold slug wells at the end of both primary and secondary runners must be provided. Trapezoidal runners can be used if necessary, but half round runners should be avoided. Gate type, dimension and location depend on the product design and on polycarbonate grade and its viscosity. All types of gates, namely pin point, diaphragm, film, tunnel, fan, tab, spider, ring, etc, could be successfully used for polycarbonate. For natural polycarbonate the pin point gate diameter should be between 0.8-2 mm. A maximum land length of 0.5 to l mm is recommended in case of diaphragm gating. In case of tunnel gate, the minimum diameter for natural polycarbonate should be 0.8 mm. In deciding the location of the gate following points should be kept in mind:

a) Gate should be placed preferable in the thickest section of the part,
b) Gate location should minimize weld lines,
c) Gate should-direct air towards the vents, and
d) Location should facilitate degating.

Like the sprue, runner and gating the location and design of venting is also important. Improper venting could cause air entrapment in the mould leading to localized burning, sinks, short shots, high moulded in stress, etc. For shallow articles, 0.02 to 0.05 mm thick vents should be placed at intervals of 2 to 4 cm around to cavity periphery, which allows venting of air on the split lines opposite the gate. Too much of venting, however, can cause reduction of air speed and can cause blockage and it can also act as potential area for flash. For more complicated and large products, venting should be decided on the basis of product and mould design.

A-3.2 Injection Moulding Conditions

The product, mould design and the MFR of the material used decide the temperature condition in injection moulding of polycarbonate. Depending on melt flow temperature between 280-320°C has to be achieved to ensure easy moulding and quality product. Mould temperature between 80-120°C not only helps in easy flow of melt in the mould and shorter cycle time, it also ensures stress free moulding with excellent surface finish.

Polycarbonate melt is usually highly viscous and injection pressure requirement is higher as compared to other thermoplastics. Depending on product size, gate dimension and grade used quite often injection pressure higher than 1 000 kg/ cm^2 is encountered. After or hold on pressure in case of polycarbonate moulding is about 50 percent of injection pressure. Backpressure should not exceed 10 kg/cm^2. Like other parameters, injection speed also depends on part intricacies, the mould quality and the gating system. Fast injection speed is, however, desirable to avoid premature freezing of the melt and knitting around corners. Slow injection speed should be used during start up. To facilitate release of part from mould, sometimes use of mould release agent like silicones spray or zinc stearate spray might be required. If, however, the parts need painting or decorating use of release agent should be avoided. These release agents should never be mixed with the polycarbonate granules.

A-4 MACHINING

Polycarbonate sheets can be machined using ordinary workshop equipments. Cooling is not necessary under normal conditions, but at higher cutting speeds, cooling with air or water is recommended. Oil emulsions should not be used for cooling purposes. No sharp corners or notches should be left on the sheet after machining as they may lead to part failure.

A-4.1 Sawing

Ordinary band saws and circular saws can be used to cut polycarbonate sheets. Due to heat resistance characteristics of polycarbonate, blade speed and cutting rate are not very critical. Tungsten carbide tipped saw blades should be used. To achieve clean cut following recommendations should be observed (*see* Fig. 3).

	Circular Saw	*Band Saw*	
Clearance angle	20-30°	20-30°	For single sheet less than 3mm, thick, band saws routers or shears are preferred to circular saws
Rake angle	1-5°	0-5°	
Shaft speed	2500-4000 rev/min		
Blade or band speed	1800-2400 m/min	600-1000 m/min	
Tooth spacing	9-15 mm	1.5-2.5 mm	

NOTE — Polycarbonate sheets should be clamped to the support table to avoid vibration and rough cutting.

Table 4 Conditions for Drilling

(*Clause* A-4.2)

Sl No.	Hole Diameter mm	Speed rev/min	Feed rev/min	Recommended Drill Angles
(1)	(2)	(3)	(4)	(5)
i)	3	1750	0.035-0.075	Clearance angle 15°
ii)	6	1000-1500	0.035-0.075	Rake angle 0-5°
iii)	9	600-100	0.012-0.074	Included tip angle 160-180°
iv)	12	325-650	0.075	
v)	18	350	0.075	

A-4.2 Drilling

Carbon steel twist drills have been found suitable for drilling polycarbonate sheets. To achieve best results, however, high speed carbide tipped twist drills should be used under conditions given in Table 4.

To drill larger holes, special drill bits with rake angle of at least 5° should be used (*see* Fig. 4). Sheets should be-clamped to the drilling table to avoid vibration and to minimize friction in the drill hole. Swarf should regularly be removed.

A-4.3 Shearing and Punching

Shearing or punching of polycarbonate sheets up to 3 mm thickness is quite easy. To obtain smooth cuts shear blades with rake angle of 45° or more and a clearance between the bed and the blade of 0.015 to 0.030 mm should be used (*see* Fig. 5). Shrinkage allowance of up to 5 percent should be made while punching holes.

A-4.4 Turning

For turning of polycarbonate sheet following tool parameters (*see* Fig. 6) are critical:

Clearance angle	20°
Rake angle	0-5°
Tip radius	0.5 mm
Speed	500-1000 m/min
Cutting speed	0.1-0.5 mm/rev

Tough swarf is produced during turning of polycarbonate sheet and this should not build up on machine or the tool. At higher cutting speed, turning should be stopped periodically to cool the work piece with air or water

A-4.5 Milling

Universal milling machine can be used for polycarbonate sheets. Apart from ordinary metal working tools high speed knife cutters can be used also. To achieve good results following parameters are important:

Clearance angle	20-25°
Rake angle	0-5°
Speed of milling cutter	100-500 rev/min
Cutting speed	0.1-0.5 mm/rev

A-4.6 Tapping

Standard metal working taps are recommended for polycarbonate sheets. Taps that produce threads with root diameters slightly rounded arc preferred. To avoid excessive heat build-up tapping should be done gently. Cutting oils or emulsions should preferably not be used

A-5 BENDING

A-5.1 Cold Bending

Practically all polycarbonate sheets excepting those with abrasion resistance special hard surface coating can be installed with a curve under stress. The minimum radius of curvature recommended for compact polycarbonate sheets is 150 times the sheet thickness while the same for multi-walled hollow structured sheets is 175 times the sheet thickness. With this minimum recommended radius, impact resistance, transparency or weather ability of polycarbonate sheets remain unaffected.

A-5.2 Cold Line Bending

Sheet thickness, tool edge and angle of bending determine the mechanical cold bending results. Blunt tool edges should be avoided. Sufficient time (about 2-3 s) for immediate sheet relaxation after bending should be allowed. Assembling should be undertaken only after relaxation for 5 to 10 days. During installation any forced reduction of bending angle must be avoided. Since cold bent sheets are under internal stress, the impact resistance of sheets is reduced. This limit use of cold bent sheets in less demanding applications.

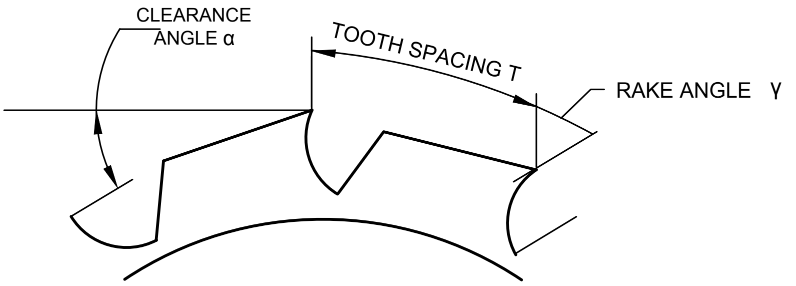


Fig. 3 Details of Saw Blades

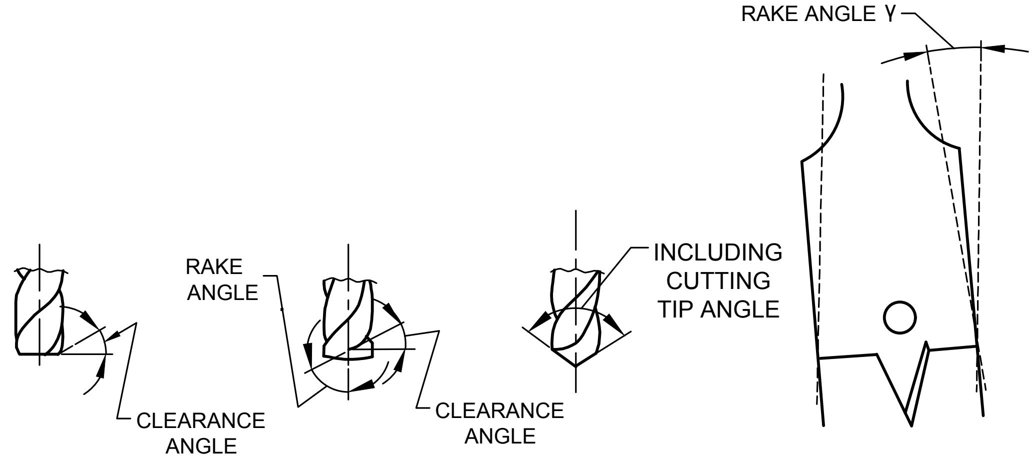


Fig. 4 Details of Special Drill

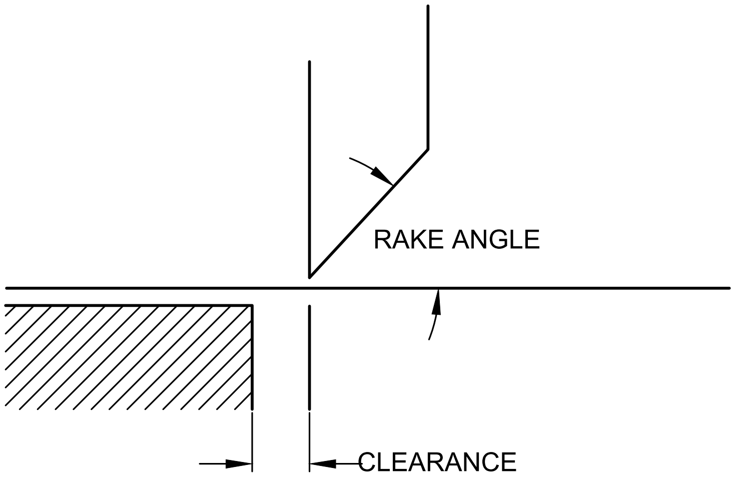


Fig. 5 Details of Shear Blades

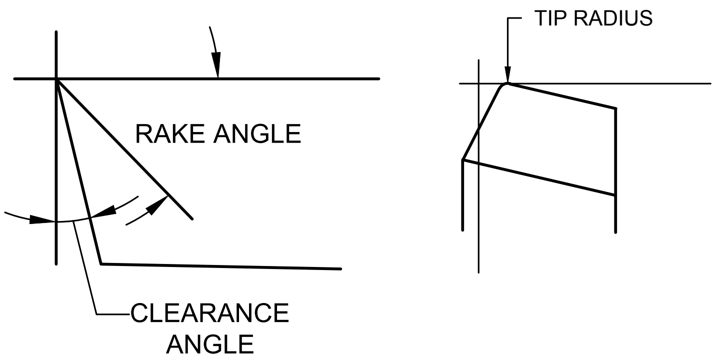


Fig. 6 Details of Parameters Used for Turning

A-5.3 Hot Line Bending

Polycarbonate sheet is locally heated to 155-160°C in this method by an electrical resistance wire with single heating the sheet must be turned over several times. After desired heating level is achieved, the sheet is bent to the required angle. For better tolerance and higher productivity, bending machines with temperature controlled heaters on both sides should be used.

A-6 ASSEMBLY

In the process of fabricating parts from polycarbonate sheet, it might be required to bond it with another piece of plastics including polycarbonate or glass or metal. The bonding technique that can be adopted depends on the part configuration, strength requirement, flexibility, heat resistance etc. Ease of bonding and appearance also have major role to play. Adhesive bonding, mechanical fastening or welding can be successfully used to bond polycarbonate sheet.

A-6.1 Adhesive Bonding

Inherent stress level, temperatures, time of exposure and nature and concentration of chemicals determine the chemical resistance behaviour of polycarbonate sheets. Many of the usual solvents used in manufacture of adhesives are known to cause stress cracking of polycarbonate. Selection of adhesive, should therefore, be made on the basis of practical data pertaining to the actual stress conditions and end-use requirements. Many of the epoxy and polyurethane based adhesives and polycarbonate solutions in methylene dichloride have widely been found useful in polycarbonate sheets fabrication.

A-6.2 Mechanical Fastening

Pop rivets are widely used in fastening polycarbonate sheets mechanically. Only aluminium rivets are recommended. The rivet head should be 2.5-3 times the diameter. Drilling of oversized holes is recommended to ~accommodate thermal expansion of rivets. Aluminium and neoprene washers should be used to spread out the load Application of small amount of silicone fluid in the hole reduces chance of stress cracking and environment attack. Even spreading of rivets helps to minimize possibility of localized overstressing. The above recommendations are also true if nut and bolts are used. Non-rusting type nuts and bolts should be used and nuts should not be tightened too firmly.

A-6.3 Welding

Traditional welding is not a recommended technique as a large scale production method for jointing of polycarbonate sheet based parts. For small volume or proto-type part production, however, it can be used successfully. The parts and the welding rod (a strip cut from polycarbonate sheet) must be pre-dried as per standard practice. The parts are put next to each other with minimal separation. The hot air temperature should be set around 475-500°C.

Ultrasonic spot welding technique when used to join polycarbonate sheets results in high mechanical performance and low residual stress. More than 70 percent of tensile strength of polycarbonate sheet can be attained in the bonded areas using this fast and effective technique. Use of high ultrasonic amplitude is recommended. A fillet radius should be included at the root of the stud to reduce stress concentration and to prevent possible breakage in this area caused by high vibrational energy.

A-7 FINISHING

Most common finishing operations that are conducted on polycarbonate sheet parts are painting and printing. Since both paints and printing inks are largely based on organic solvents which are known to have adverse effects on polycarbonate, selection of these should be based on stress level in the parts and practical experience of efficiency of a particular paint or ink system in similar conditions of use.

A-7.1 Painting

Standard spray painting technique can be adopted; cleaning of the surface is a must prior to painting. Both single and two component epoxy and polyurethane paint systems have been developed for painting on polycarbonate surface. Single coat and multi-coat systems are available within the available range of paints. If cut and spray technique is employed, care should be taken to avoid deep cuts in the sheet surface while cutting through the masking layer. Notches created by deep cuts may cause impact failure in the parts.

A-7.2 Screen Printing

Screen printing of polycarbonate sheets is similar to the technique adopted for other materials. Vinyl and acrylic based inks are found suitable. However, selection of ink should be based on similar judgement as recommended in case of paints. Thinner, if used, should be as per manufacturer's recommendations.

A-7.3 Anti-Static Treatment

Polycarbonate sheets are good electrical insulator. Machining or handling of polycarbonate sheets usually result in accumulation of static charge on the surface. Surface treatment with proper antistatic agents reduces the possibility of static charge build up in polycarbonate sheets. Proprietary antistatic formulations are available from chemical manufacturers like American Cyanamide Co. AKZO and BEE Chemical Co.

A-7.4 Cleaning

Surface cleaning of polycarbonate sheets is required before and/or after various finishing operations. Sometimes this might be required even before forming. Recommended clearing agents are mild detergent dissolved in water, isopropyl or isobutyl alcohol and clean water. Use of soft cloth or sponge helps in cleaning. Paint splashes, greases, dirt, etc can be removed easily before drying by rubbing lightly with cotton moistened with methylated spirit or petroleum ether. A wash with mild soap solution and clean water should follow. To avoid water spots the surface should be dried thoroughly with a chamois or moist cellulose sponge. Abrasive or highly alkaline cleaners should never be used on polycarbonate sheets. Surface should also not be scrapped with razor or any other sharp tool. In case of heavy dust build up, an ionising air gun should be used to remove the dust. It should be followed by wiping with soft cloth dipped in water or 4.5percent isopropyl alcohol.

A-8 INSTALLATION

Polycarbonate sheets of both compact and multi-walled hollow varieties are extensively used in building and construction industry. Architectural and engineering design for any installation should be guided by factors like wind load and snow load (wherever applicable) on the installation. Data related to span width, radius of curvature and sheet thickness, etc in relation to loading are available from sheet suppliers and should be used judiciously. Depending on sheet thickness and possible loading the edge engagement of sheet is determined. Since thermal expansion of polycarbonate sheet is relatively higher, the rebate depth (depth of fixing profile) should be calculated and maintained accurately to avoid deformation of sheet after installation. Rain water drainage should be ensured in case of horizontal installation by maintaining a slope of 9 cm/m length of sheet. Wood or metal profiles can be used as structural support. General recommendations given below should be followed during installation of sheets:

a) Edge engagement and expansion allowance should be calculated.

b) Sheets are to be cut to exact size and edges should be free from cuts and notches.

c) 50 mm of masking should be removed from all edges.

d) Suitable gaskets or sealants should be used at the edges.

e) Masking should be completely removed soon after completion of installation.

f) Sheets should be cleaned with mild soap solution and soft cloth after installation is over.

g) In case of UV coated sheets, the coated side should always face the outside. No solvent should be used to clean this coated surface.

Sealant should be used not only to secure the sheets properly with the supporting frame but also to eliminate possibility of leakage. Keeping the expansion and contraction the sheet undergoes due to temperature fluctuations, the sealant should accommodate certain amount of movement without loss of adhesion with frame or sheet. Silicone and polysulphide sealants and polybutene tapes have been found suitable in this respect and are used quite often. However, chemical compatibility of the sealing system with polycarbonate sheet has to be established before use during installation Where expansion and contraction of sheet exceeds the limitation of such sealants, neoprene or EPDM rubber gaskets of about 65 shore hardness can be used, the gasket is snap fitted into the glazing bars to allow free movement of the sheet during thermal expansion or contraction. Moreover, use of such gasket has aesthetic value as well.

ANNEX B

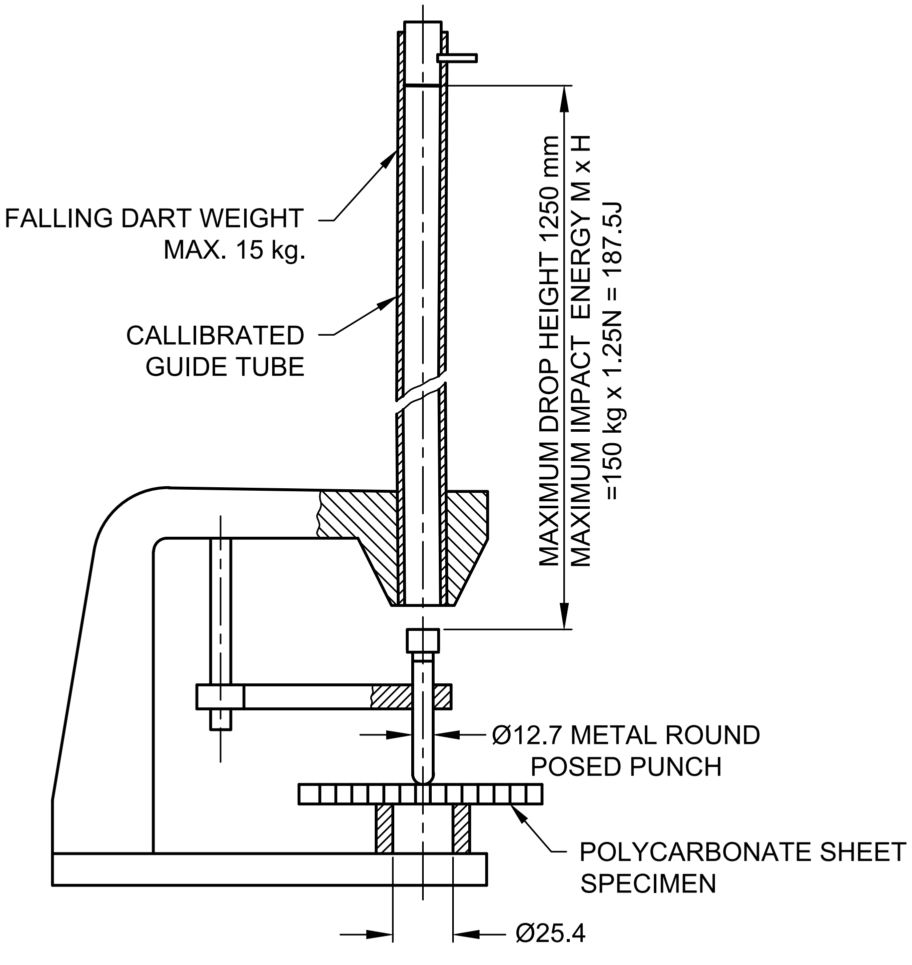
(*Clause* **3.2.5**)

DART DROP IMPACT STRENGTH

B-l A Gardner Impact Tester (*see* Fig. 7) is used for testing dart drop impact strength of polycarbonate Shields. The specimen is placed over a hole of 25.4 mm diameter in a die mounted on the anvil. A round nosed dart, 12.7 mm diameter is placed upon the specimen. A dart with a variable mass of up to 15.0 kg is raised to the desired height in a 1.25 m calibrated tube and dropped. The maximum applied impact energy is given as:

$$M \times n = 15.0\ \text{kg} \times 1.25\ \text{m} = 18.75\ \text{kg.m}\ (187.5\ \text{J})$$

A slight reduction in the maximum energy may occur due to the zero adjustment necessary for the various thicknesses of the specimen. The test specimen considered to have passed the test, if the sample shows no visible signs of surface cracking around the impact area.


FALLING DART WEIGHT MAX. 15 kg.
CALLIBRATED GUIDE TUBE
MAXIMUM DROP HEIGHT 1250 mm
MAXIMUM IMPACT ENERGY M x H
=150 kg x 1.25N = 187.5J
Ø12.7 METAL ROUND POSED PUNCH
POLYCARBONATE SHEET SPECIMEN
Ø25.4

All dimensions in millimetres

FIG. 7 GARDNER IMPACT TESTING MACHINE

ANNEX C

(*Clause* 3.2.5)

DETERMINATION OF FLAMMABILITY

HORIZONTAL BURNING TEST FOR CLASSIFYING MATERIALS 94HB

C-1 TEST CRITERIA

A material shall be classified 94HB on the basis of test results obtained on small bar specimens when tested as described in **C-4** to **C-12**.

C-2 A material classed 94HB shall (*see* also **C-3**):

a) Not have a burning rate exceeding 38.1 mm per min over a 76.2 mm span for specimens having thickness of 3.05 to 12.7 mm, or

b) Not have a burning rate exceeding 76.2 mm per min over a 76.2 mm span for specimens having a thickness less than 3.05 mm, or

c) Cease to burn before the flame reaches the 102 mm reference mark (*see* C-10).

C-3 If only one specimen from a set of three specimens does not comply with the requirements, another set of three specimens is to be tested. All specimens from this second set shall comply with the requirements in order for material in that thickness to be classified 94 HB.

C-4 APPARATUS

The apparatus employed is to consist of the following:

a) *Test chamber, enclosure or laboratory hood* — Free of induced or forced draft during tests.

b) *Laboratory burner* — A Bunsen of Tirrill burner having a tube with a length of 80 to 100 mm and an inside diameter of 94 +1.6 - 0.0 mm. The tube is not to be equipped with an end attachment, such as a stabilizer.

c) *Wire gauze* — A 20 mesh (20 openings per 25.4 mm), 0.43 mm diameter iron wire gauze, 127 mm square.

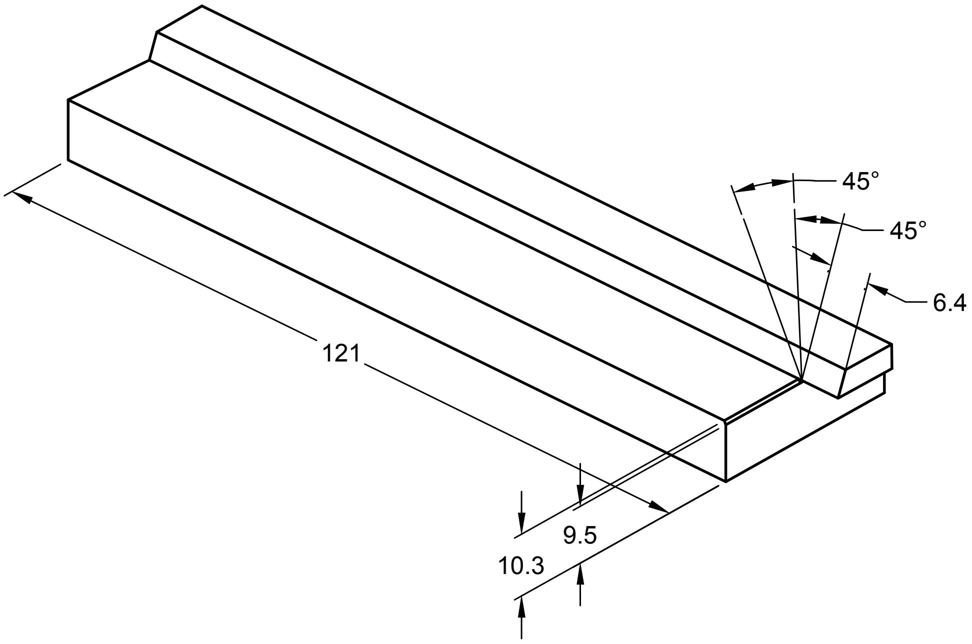
d) *Gas supply* — A supply of technical grade methane gas with regulator and meter for uniform gas flow. Natural gas having a heat content of approximately 37 MJ/m^3 has been found to provide similar results. Other fuel gases, such as butane, propane and acetylene (which have a higher heat value) may also be used. However, technical grade methane gas shall be used in case of dispute.

e) *Ring stand* — A ring stand with clamps, or the equivalent for horizontal positioning of the specimen and the wire gauze.

f) *Stopwatch* or other timing device.

g) *Conditioning room or chamber* — Capable of being maintained at 27 ± 2° C and a relative humidity of 65 ± 5 percent.

h) *A Metal support fixture* — As illustrated in Fig. 8 for testing specimens that sag or bend at their free end.



All dimensions in millimetres

Fig. 8 Flexible Specimen Support Fixture

C-5 TEST SPECIMENS

Test specimens are to be limited to a maximum thickness of 12.7 mm. Test specimens of a 127 mm length by 12.7 mm width are to be provided in the minimum thickness and in a 3.18 ± 0.13 mm thickness. The 3.18 ± 0.13 mm thick specimens are not necessary if the minimum thickness is greater than 3.18 ± 0.13 mm or the maximum thickness is less than 3.18 ± 0.13 mm.

Exception: A material classified 94HB in the 3.18 ± 0.13 mm thickness shall automatically be classed 94HB down to a 1.57 mm minimum thickness without additional testing.

C-5.1 The specimens are to comply with the following:

a) The maximum width is to be 13.2 mm; and
b) The edges are to be smooth, and the radius on the corners is not to exceed 1.3 mm.

C-5.2 If a material is to be considered in a range of colours, melt flows, or reinforcements, specimens representing these ranges are also to be provided. Specimens in the natural (if used in this colour) and in the most heavily pigmented light and dark colours are to be provided and considered representative of the colour range, if the test results are essentially the same. An additional set of specimens is to be provided in the heaviest organic pigment loading, unless the most heavily pigmented light and dark colours include the highest organic pigment level. When certain colour pigments (for example, red, yellow, or the like) are known to have particularly critical effects, they are also to be provided. Specimens in the extremes of the melt flows and reinforcement contents are to be provided and considered representative of the range, if the test results are essentially the same. If the burning characteristics are not essentially the same for all specimens representing the range, evaluation is to be limited only to the material in the colours, melt flows, and reinforcement contents tested, or additional specimens in intermediate colours, melt flows, and reinforcement contents are to be provided for tests.

C-6 SPECIMEN CONDITIONING

The specimens are to be conditioned for at least 48 h at 27 ± 2°C and a relative humidity of 65 ± 5 percent, prior to testing.

C-7 TEST METHOD

The burning test is to be conducted in a chamber, enclosure, or laboratory hood free of induced or forced draft. An enclosed laboratory hood with a heat-resistant-glass window and an exhaust fan for removing the products of combustion after the test is recommended.

C-8 Each specimen is to be marked across its width with two lines, 25.4 and 102 mm from one end of the specimen. The specimen is to be clamped at the end farthest from the 25.4 mm mark, with its longitudinal axis horizontal and its transverse axis inclined 45°. The wire gauze is to be clamped horizontally beneath the specimen, with a distance of 9.5 mm between the lowest edge of the specimen and the gauze, and with the free end of the specimen even with the edge of the gauze. (*see* Fig. 9).

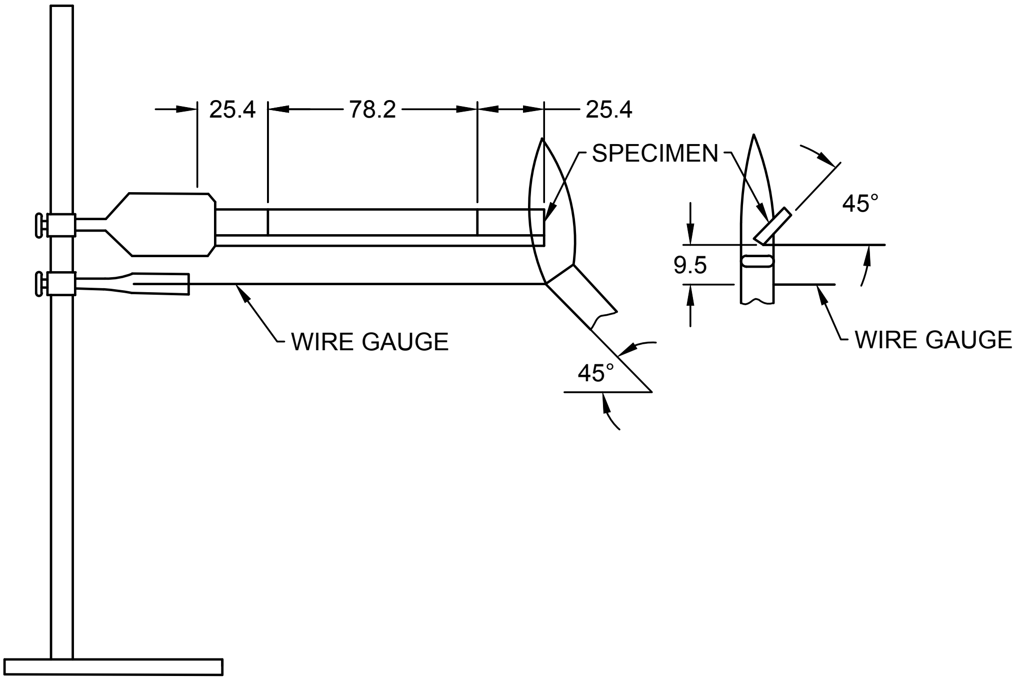


Fig. 9 Horizontal Burning Test for 94HB Classification

C-8.1 If the specimen sags at its free end during the initial set up, the support fixture illustrated in Fig. 8 is to be positioned under the specimen with the small extending portion of the support fixture 19 mm from the free end of the specimen. Enough clearance is to be provided at the clamped end of the specimen so that the support fixture can be freely moved sideward. As the flame front progresses along the specimen, the support fixture is to be withdrawn at the same rate.

C-9 The burner is then to be placed remote from the specimen, ignited, and adjusted to produce a blue flame 25 mm high. The flame is to be obtained by adjusting the gas supply and the air ports of the burner until a 25 mm yellow tipped blue flame is produced and then the air supply is to be increased until the yellow tip disappears. The height of the flame is to be measured again and corrected if necessary. The flame is to be applied to the free end at the lower edge of the specimen. The centre axis of the burner tube is to be in the same vertical plane as the longitudinal bottom edge of the specimen (and inclined toward the end of the specimen) at an angle of approximately 45° to the horizontal (*see* Fig. 9). The flame is to be applied so that the front edge of the specimen, to a depth of approximately 6.4 mm, is subjected to the test flame for 30 s without changing the position of the burner and is then removed from the specimen. If the specimen burns to the 25.4 mm mark before the flame has been applied for 30 s, the flame application is to be discontinued when the flame reaches the 25.4 mm mark.

C-10 If the specimen continues to bum after removal of the test flame, the time for the flame front to travel from the mark 25.4 mm from the free end to the mark 102 mm from the free end, is to be determined and the rate of burning is to be calculated.

ANNEX D

(*Clause* 3.3.5)

(Informative)

LIST OF ACCESSORIES CONVENTIONALLY USED IN POLYCARBONATE PROTECTIVE SHIELD

D-1 ARM PAD

a) Fabric — Polyester 100 gsm,
b) Thread — Polyester,
c) Velcro (12 mm), and
d) Foam (12 mm).

D-2 SHOULDER BELT

a) Belt Fabric — Polypropylene (PP) (30 mm),
b) Push Lock — Acrylonitrile Butadiene Styrene (ABS),
c) Adjuster — Acrylonitrile Butadiene Styrene (ABS), and
d) MS Buckle.

D-3 HARNESS SHIELD ARM BELT

Fabric — Velcro (12 mm).

D-4 STICKER (IF ANY)

Material — High Impact Polystyrene (HIPS) Sheet.

D-5 OTHER ACCESSORIES

a) Nylon lock nut,
b) SS304 hex-headed M6 bolts on handle, and
c) EPDM [Ethylene Propylene Diene Monomer (M-class)] washers and inserts for handle.

ANNEX E

(*Clause* 5)

SAMPLING OF POLYCARBONATE SHIELDS

E-1 SCALE OF SAMPLING

E-1.1 Lot

In a single consignment all the shields of identical dimensions belonging to the same batch of manufacture shall be grouped together to constitute a lot.

E-1.2 For judging conformity to the specified requirements each lot shall be considered separately.

E-1.3 The number of sample shields from a lot for determining the conformity shall be in accordance with col 2 and col 3 of Table 5.

E-1.4 The sample shield shall be taken at random from the lot. In order to ensure randomness of selection, random number tables may be used (*see also* IS 4905).

E-2 NUMBER OF TESTS AND CRITERIA FOR CONFORMITY

E-2.1 Each of the sample shield selected according to **E-1.3** shall be tested for all the requirements of this specification. The lot shall be declared to be in conformity if each sample sheet individually meets the specified requirements.

Table 5 Number of Sample Sheets

(*Clause* E-1.3)

Sl No. (1)	Number of Shields in a Lot N (2)	Number of Sample Shields n (3)
i)	Up to 25	1
ii)	26 to150	2
iii)	151 to300	3
iv)	301 to 500	4
v)	501 and above	5

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This Indian Standard has been developed from Doc No.: PCD 12 (11138).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi